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SOME NEW RESULTS ON STATISTICAL IMAGE SEGMENTATION*

by

C. H. Chen
Electrical Engineering Department
Southeastern Massachusetts University
North Dartmouth, Massachusetts 02747

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1. Introduction

Three major approaches to the image segmentation are the cluster-based segmentation, edge detection and region extraction [1]. For the images with the well-defined-shaped objects in a background scene, edge detection of the object is a good approach. However, the regions in most images are not well defined. The cluster-based and the region extraction procedures are more useful for the segmentation purpose. As a continuing effort on the statistical image-segmentation study, some new techniques are examined in cluster analysis and region extraction. Furthermore, the Fisher's linear discriminant is extended to a three-class case. New results based on these techniques are presented in this report. These results illustrate the effectiveness of the statistical image segmentation for the reasonably complex scenes such as the human face and the topographic pictures.

2. Use of Color Information in Iterative Thresholding

Color provides an important dimension in all image studies. Use of color information as an aid to image segmentation has been examined (see Refs. [2] [3] [4]). For our AED512 Color Image Process-ing and Graphics terminal, an efficient feature-extraction procedure has been developed. By using the color features selected, an iterative thresholding method is used to segment or partition the scenes into parts.

Figure 1a is the Kodak color girl image studied. Let R, G, B be the original tristimuli, Red, Green and Blue; and Q_R, Q_G, Q_B be the quantized pixel gray levels from the R, G, B subimages respectively. The color features extracted are

$$x(1) = (Q_R x 42) + (Q_G x 36) + (Q_B x 36)$$

$$x(2) = R - G$$

$$x(3) = (2G - R - B)/2$$

where the weighting factors are selected as

$$36: \quad I_R = \text{Integer of } (256/7)$$

$$42: \quad I_G = \text{Integer of } (256/6)$$

$$42: \quad I_B = \text{Integer of } (256/6)$$

The first feature is most important. For each feature space, the valleys of the histograms are located. Pixels in the small neighborhoods of valleys most likely belong to the object or region boundary points. The histogram of such points are determined from which the valleys of the new histogram are located. This procedure is repeated iteratively. After several iterations, only points which really belong to the region boundaries will remain and these points are assigned to level one while all other points are assigned to level zero. The resulting binary picture shown in Fig. 1b clearly illustrate all region boundaries. The procedure is more efficient than that of Ohta, et. al. [2] while the results are comparable to theirs.

A comparison is now made with the edge detection using the modified gradient method [5]. Based on the first feature, x(1), the 16-level display of the modified gradient result is shown in Fig. 1c. The modified gradients of the three original Red, Green and Blue pictures are shown respectively in Figs. 1d, e, f. The modified gradient method can be applied to all three colors, and a point is classified as an edge point if any one of the three colors decides that it is an edge point, i.e. above certain threshold of the modified gradient. The result is shown in Fig. 1g. If two out of three colors must decide that the point is an edge point, then fewer edge points are expected as shown in Fig. 1h. Fig. 1b shows much better boundary continuity than the others while Fig. 1c with a multi-level display provides many fine details of the image.

Another color image as shown in Fig. 2a is also examined. Fig. 2b is the result of the iterative thresholding which clearly indicates the roads and rivers in the original scene. Fig. 2c is the modified gradient result based on the decision criterion that at least one color must classify the point as an edge point in order to assign the point to the level 1. Fig. 2d is another modified gradient result that requires two colors to classify the point as an edge point. As expected Fig. 2d has fewer edge points but still provides much details of the original scene. In this example, Fig. 2b is far superior to Fig. 2c or Fig. 2d in image segmentation. The iterative thresholding method for the color image segmentation provides an efficient automatic region extration procedures that preserves, as shown in the illustrative examples, the region boundaries. The color information has been shown to be very useful for a better segmentation.

3. Fisher's Linear Discriminant

For segmenting an image into two regions (classes), the

Fisher's linear discriminant has been shown to be very effective in our recent work [6] [7]. For the three-class case, an experiment is performed on a different image as shown in Fig. 3a. In this case two classes are not adequate to segment the image meaningfully. With the assumption of three classes, Fig. 3b is the segmentation result based on the Fisher's linear discriminant. The result is superior to the threshold-selection method using two thresholds. The features employed for Fig. 3b are based on the local properties [7]. A pairwise decision is made and the final decision is based on the majority vote. For more than three classes, the number of pairwise decisions increases rapidly with the number of classes and the Fisher's linear discriminant is obviously not suitable for more than three classes.

4. Segmentation by Automatic Spatial Clustering

Spatial clustering is useful to segment the image without requiring the knowledge of the number of clusters or classes. The procedure suggested by Fukada [8] is interesting but the existence of undefined region is undesirable in practice. A new procedure is developed that can automatically determine the number of classes. As the size of the image considered is large, spatial compression is performed by using the simple averaging procedure.

The topographic image used for the experiment contains 2048x2048 pixels. Only one-fourth of the original picture is considered here. The 1024x1024 image is compressed to a 256x256 image as shown in Fig. 4a. For each 4x4 subimage in the original picture the mean (m) and gradient (g) are computed to form a feature vector $x' = (m,g)$. Each pixel is now represented by such feature vector. For each 2x2 subarea, measure the mean vector (M) and dispersion σ_o^2 which is the trace of the covariance matrix of x. Determine the critical dispersion θ that discriminates the feature space into most separated regions using the corresponding merging distance suggested [8],

$$d_o = \sqrt{\frac{4}{3}(\theta - \sigma_o^2)}$$

Among the candidate vectors, we can choose as many vectors as we like to be the starting vectors for clustering. Applying the K-mean algorithm [9], it is possible to converge to some final cluster centers. By using these candidate vectors we can easily classify the image pixels into corresponding regions. Fig. 4b is the result of spatial clustering that sets to 8 clusters. The processed result clearly shows contrast enhancement over the original picture. If we consider one-fourth of Fig. 4a, the compressed picture (128x128) is shown in Fig. 5a. By specifying 4 clusters, the processed result is shown in Fig. 5b. The procedure can automatically set to 9 clusters as shown in Fig. 5c. For the topographic pictures considered, the number of classes or segments are unknown to begin with. The spatial clustering method as presented appears to be very suitable for segmentation of such images. Further work will make use of the city-block distance [10] and the split-and-merge method.

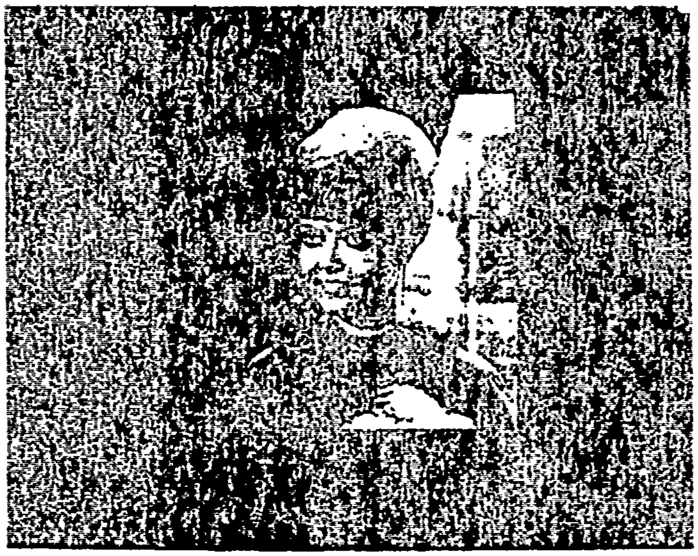
Fig. 1a

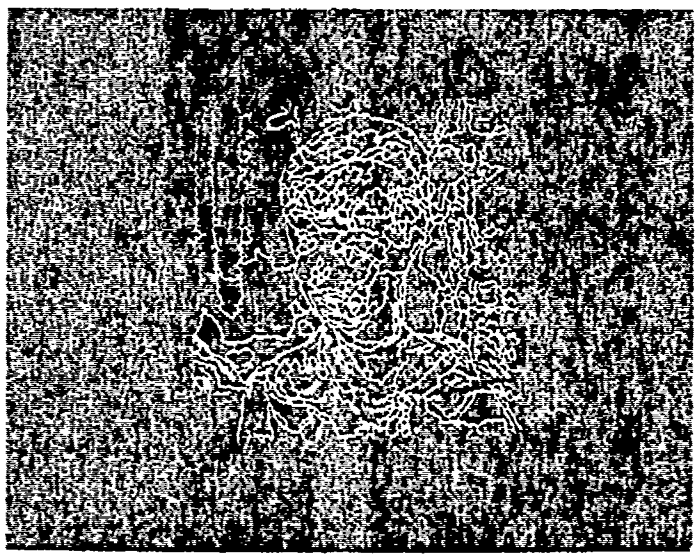
Fig. 1b

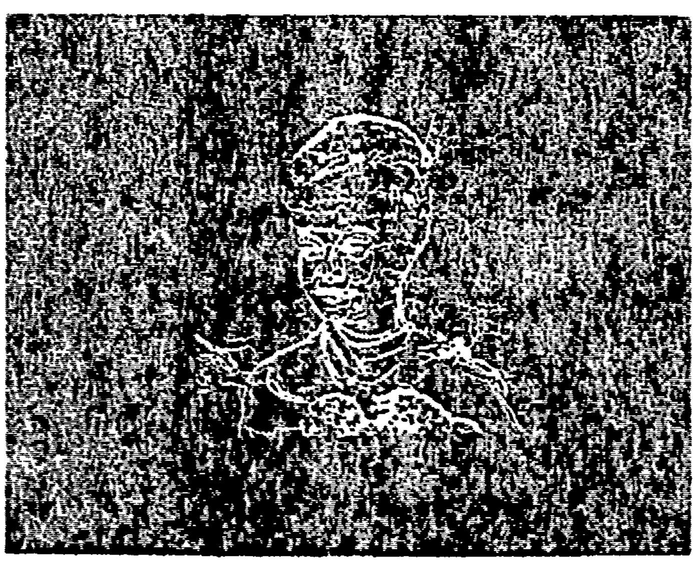
Fig. 1c

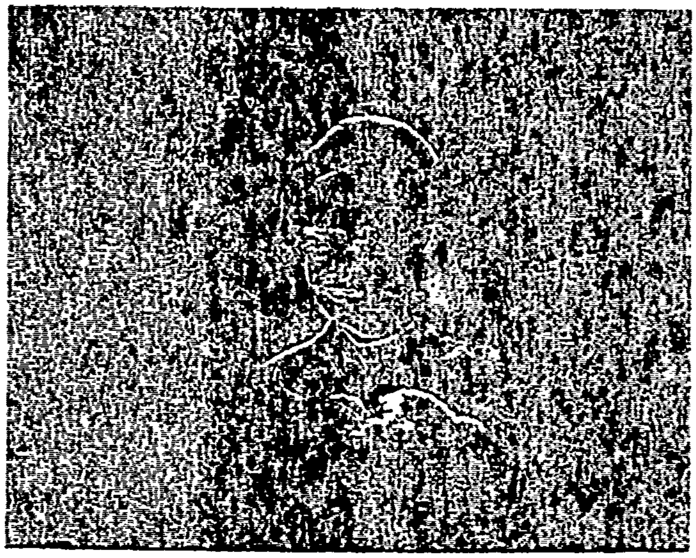

Fig. 1d

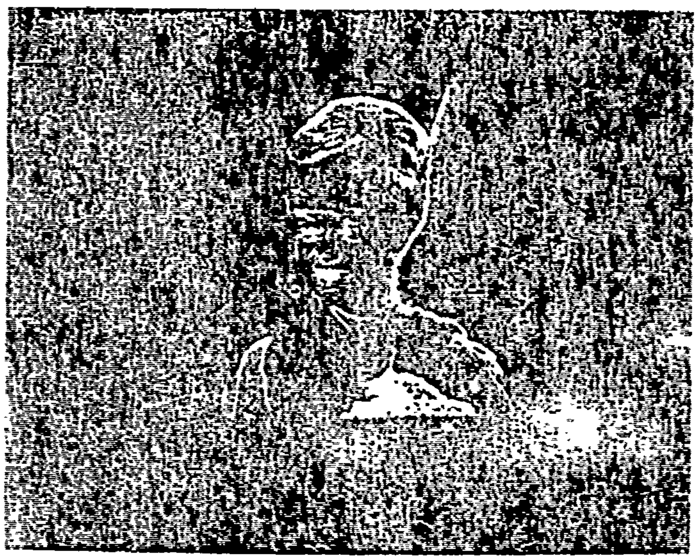

Fig. 1e

Fig. 1f

Fig. 1c

Fig. 1b

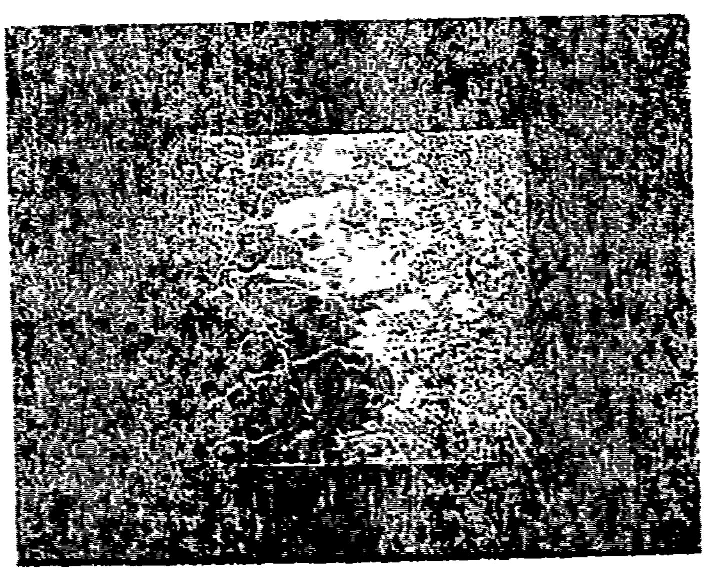

Fig. 2a

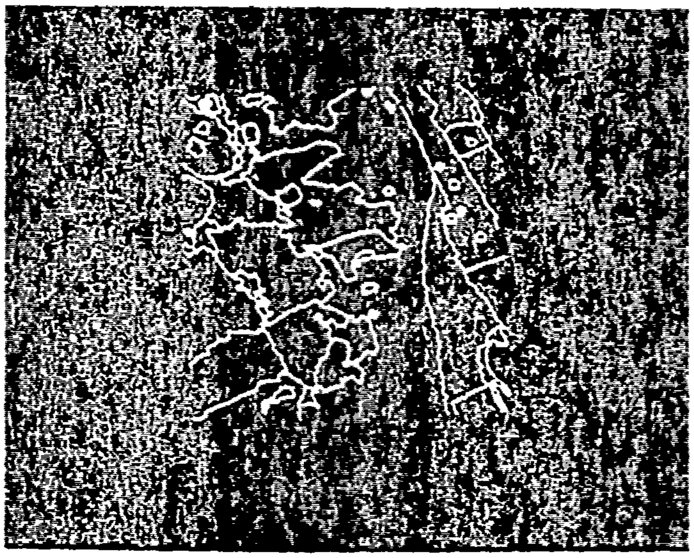

Fig. 2b

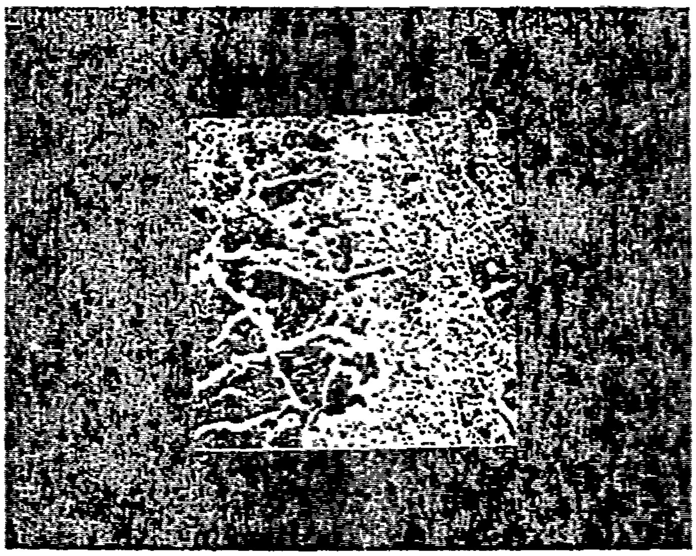

Fig. 2c

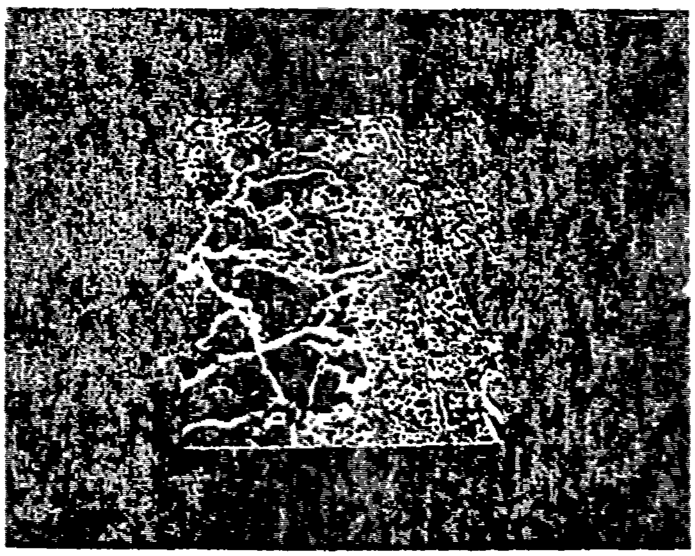

Fig. 2d

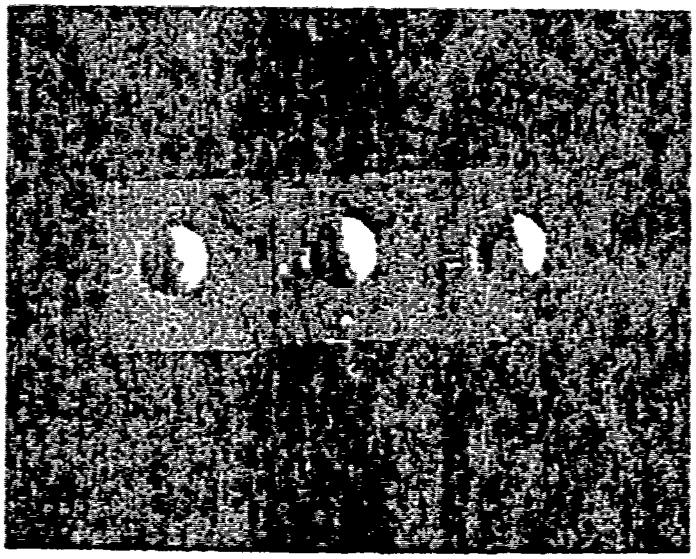

Fig. 3

3a 3b 3c

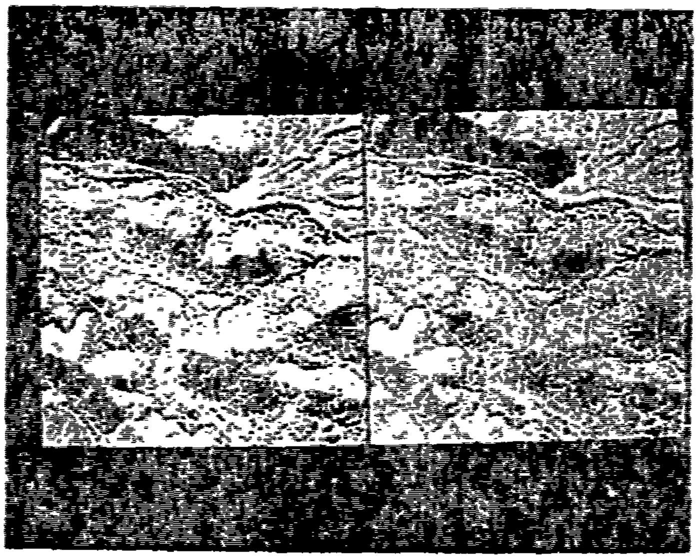

Fig. 4

4b 4a

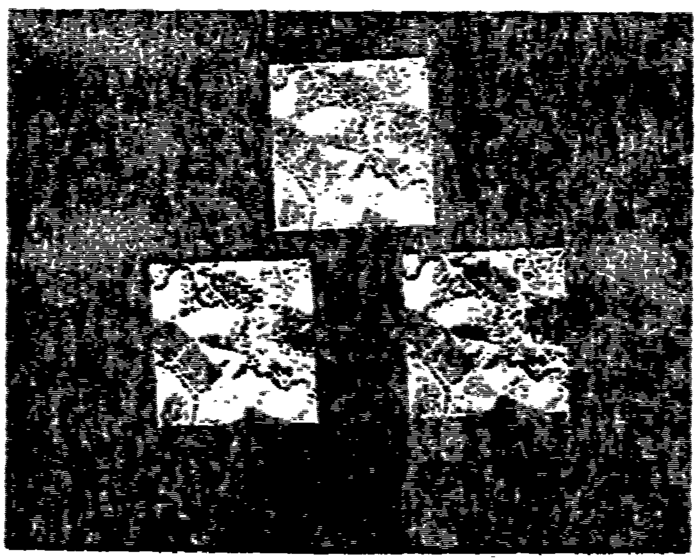

Fig. 5

5a

5b 5c

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

New results are presented on the statistical segmentation based on iterative thresholding for color images, Fisher's linear discriminant, and the cluster-based region growing procedure. Both human face and topographic images are used for the study.

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